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ALPINE FELL-FIELDS OF EASTERN NORTH AMERICA

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The *fjeld* of Norwegian geographers is a high, barren plateau, unfit for cultivation. The Dovre Fjeld is such a mountain plateau of the Scandinavian range, lying between latitudes 62° and 62½° in Norway and forming a continuation of the Kiölen Range. According to the Century Dictionary the word is the same as "fell" (from Middle English *fel, fell,* from Icelandic *fjall, fell* = Swedish *fjäll* = Danish *fjaeld,* a hill; perhaps connected with "field"). Plant geographers, such as Warming in the English edition of his "Oecology of Plants,"[1] render it as "fell-field," while Schröter[2] uses the term *Gesteinsfluren.* The German equivalent is *Felsenfluren,* and the Danish idea is expressed in the combination *Fjaeldmarker.* The idea of fell-field is a rocky flat, or plateau, situated in arctic or subarctic regions or on the alpine summits of mountains in northern as well as southern latitudes. The soil of a fell-field is not continuous but is broken by stones, rocks, boulders, rocky slabs, or outcropping ledges into pockets, crannies, or small areas circumscribed by the scattered or projecting rocks. Hence the surface of the fell-field is never completely covered with plants. Between the scattered patches of vegetation we see bare, pebbly, stony, sandy, or clayey soil usually devoid of humus in the ordinary acceptance of that term as meaning the organic material of the soil.

General Character of Fell-fields

Considerable attention has been paid to the fell-field formation by European phytogeographers, and our information on this subject has been summarized admirably by Eugen Warming.[3] He describes the subglacial, arctic, antarctic and tropical fell-fields, as also those of the European mountains, and those of the mountain steppes, such as the *punas* of the Andes. According to Warming's summary the most characteristic feature of the vegetation of the fell-fields is the dwarfishness of the plants and the poverty of individuals covering the bare surface. The abundance of cryptogams, such as lichens and mosses, is noteworthy. The flora of these rocky flats may be considerably diversified, one species rarely predominating. The seed plants assume the cushion, or tufted, form and possess a perennial, strong tap-root which establishes itself in the soil pockets or descends considerable distances into the clefts or crannies between the rocks. Dwarf shrubs occur, and these are mostly evergreen. The nanism, or dwarfishness, of the herbs and shrubs is associated with high winds, the shortness of the vegetative season, and the low temperature of the air and soil. The persistence of snow partially accounts for the low temperature. The illumination is more intense on the alpine fell-fields of European mountains and the Rocky Mountains and Sierra Nevada of America. It is a well-known fact that the intensity of direct sunlight, which inhibits the growth of alpine plants, increases with altitude, because the air is more rarefied and absolutely more dry. The fluctuation of the air temperature is greater on high mountain tops than on the plains at their base. The high winds of mountain summits have an intense drying action on plants, and, although the roots of the alpine species may reach abundant water supplies in the soil, there are various structural features by which the loss of water from the plant is compensated, such as the concealment of the stomata in furrows or under the revolute leaf margins or under hairs.

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[1] Eugen Warming: Oecology of Plants, Engl. transl., Oxford, 1909, p. 256.

[2] C. Schröter: Das Pflanzenleben der Alpen, Zurich, 1908, p. 503.

[3] *Op. cit.*, pp. 248-261.

ARCTIC FELL-FIELDS IN GREENLAND AND ICELAND

Arctic fell-fields occur in Arctic North America, northern Europe, Siberia, Greenland, and Iceland. In different localities, according as the soil is more or less gravelly, clayey, or sandy, or warmer or colder owing to slope exposure, certain species occur sometimes in greater abundance and give stamp to the vegetation, so that it is possible to distinguish various associations of fell-field plants. Since Warming's work was published in English in 1909, a number of works have appeared which have thrown additional light upon the vegetation of fell-fields. Kruuse[4] describes the vegetation of the rocky-flat formation of eastern Greenland.

THE ROCKY-FLAT FORMATION OF EASTERN GREENLAND

The rocky-flat formation of eastern Greenland comprises plants which are scattered to such a degree that the bare soil appears nearly everywhere. This formation may be found in all localities, flat as well as rugged, and with every kind of slope exposure. The snow cover is thin and open, the surface often being bare of snow throughout the winter. The soil is loose gravel or sand, often shifted by the arctic gales, so that erosion is sometimes great. Vegetable mold, or humus, is practically wanting. Water is never present in quantity. Kruuse divides the rocky-flat formation into (1) the common rocky-flat formation; (2) the gravel flats; (3) the gravel-sand slopes; (4) gravel hills; (5) sandy slopes. The latter subformation corresponds probably to our coastal dunes and should not be included as part of the fell-field formation.

The common rocky-field formation is found in eastern Greenland on wind-swept plateaus, hills, and declivities where rocks rise sufficiently above the surface to keep the intervening loose soil in position. Such plants as *Empetrum nigrum, Silene acaulis, Ranunculus glacialis, Sedum Rhodiola, Diapensia lapponica, Vaccinium uliginosum* var. *microphyllum, Oxyria digyna, Salix herbacea, Lycopodium Selago* var. *appressa* are characteristic

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[4] Chr. Kruuse: Rejser og Botaniske Undersögelser i Öst-Grönland mellem 65°30′ og 67°20′ i Aarene 1898-1902, samt Angmagsalik-Egnens Vegetation, *Meddelelser om Grönland*, Vol. 49, 1912, pp. 1-304.

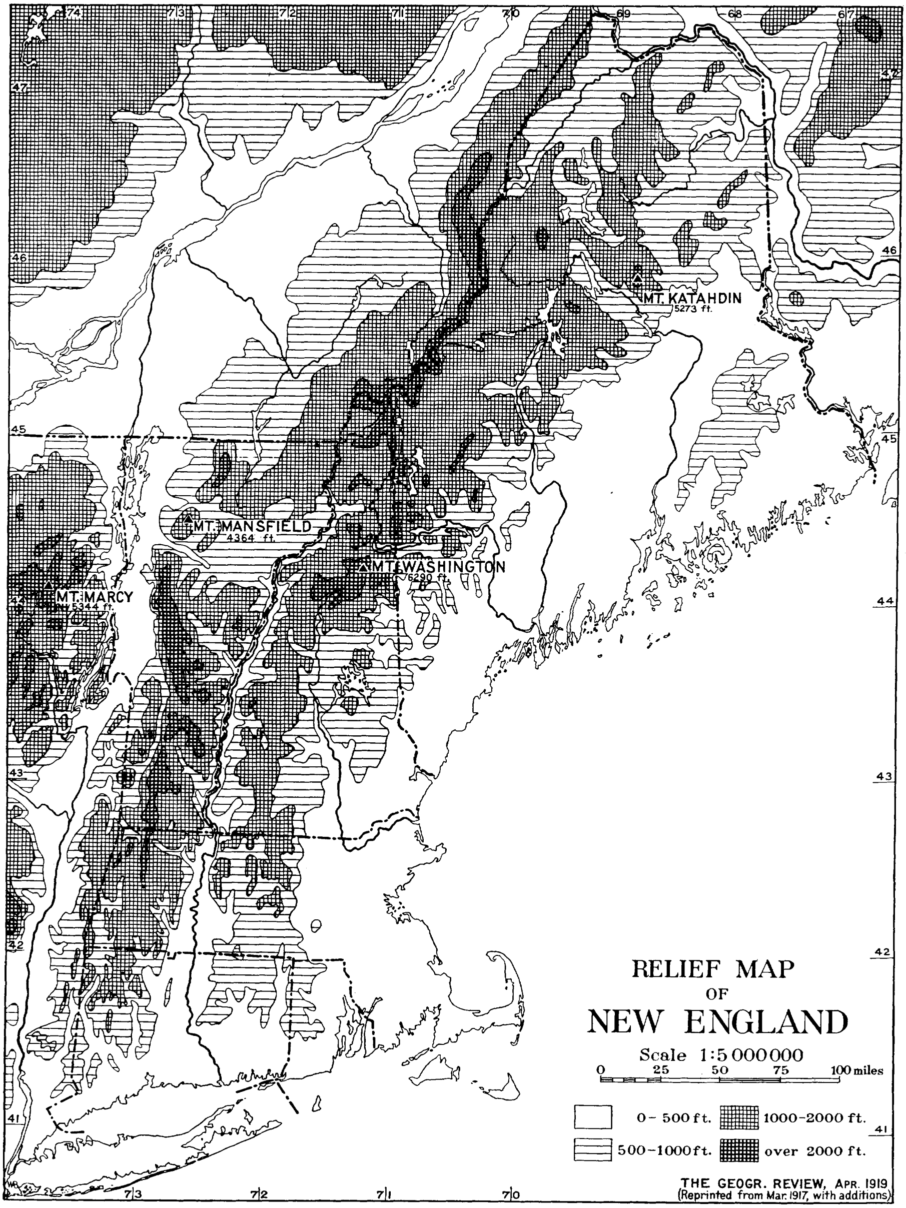

FIG. 1—Relief map of the New England region showing the location of the mountain summits bearing fell-fields discussed in the text. Scale, 1:5,000,000. (For sources used in drawing contours see the *Geogr. Rev.*, Vol. 3, 1917, p. 228, Fig. 1.)

on the Greenland *Fjaeldmark.* The gravel flats resemble the preceding but are destitute of rocks. They are replaced by coarse gravel, which is often disturbed and relaid by the winter gales. The surface is generally snowless. The flora is scanty, consisting mainly of ligneous plants, which are separated by wide intervals of soil space, frequently wind-torn and covered partially by gravel. The *Grusfladerne,* or gravel flats, are sometimes represented in marine terraces with a sparse dwarf vegetation. The gravel slopes consist of coarse gravel heaped up into steep slopes by the wind or slid down from the sides of the adjacent mountains. The vegetation consists of *Silene acaulis, Salix glauca, S. herbacea,* and *Armeria sibirica,* which have long tap-roots (2-3 meters) by which they are rendered immovable, besides *Chamaenerium latifolium, Saxifraga oppositifolia* var. *reptans, Luzula confusa,* and *Cerastium alpinum,* which, not being anchored securely, frequently slide down the slopes with the moving gravel. The gravel hills

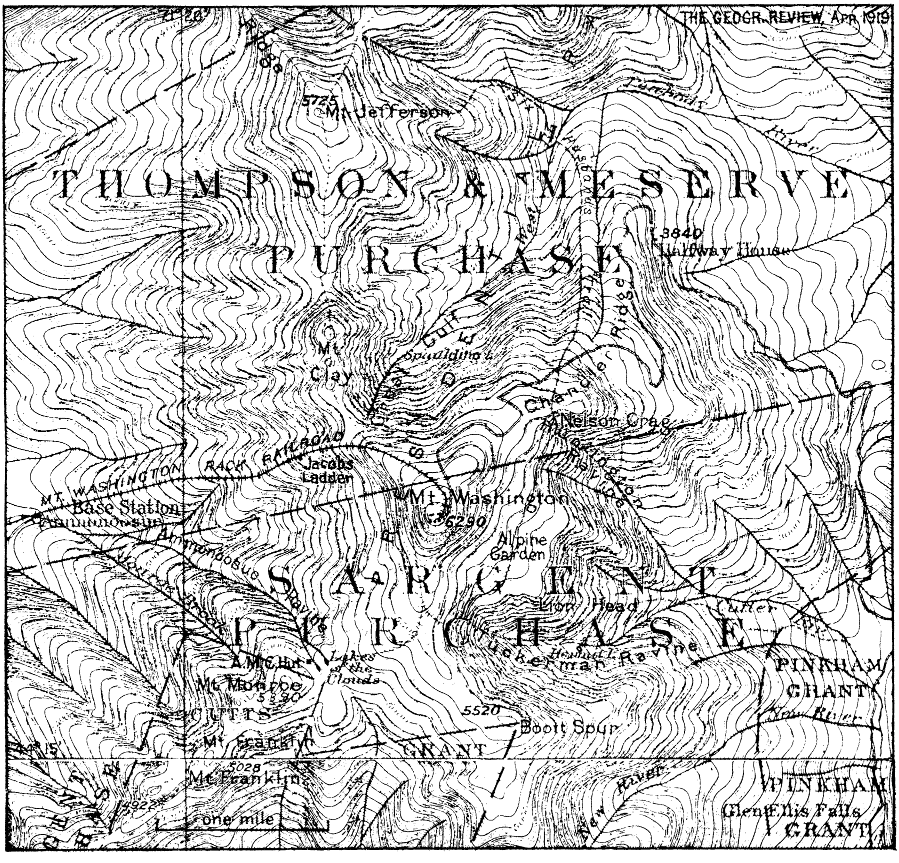

FIG. 2—Contour map of the Mt. Washington massif showing the location of the features mentioned in the text. Scale, 1:70,000. Contour interval, 20 feet. (Reproduced from the Mt. Washington and Crawford Notch, N. H., topographic sheets, 1:62,500, of the U. S. Geological Survey, 1896, with additional names.)

have a somewhat different vegetation owing to the greater stability of the surfaces, which are often broken by big rocks. *Azalea procumbens* is one of the plants of these gravel hills.

The Rocky-Flat Formation of Iceland

In Iceland, according to Th. Thoroddsen,[5] the rocky-flat formation occupies the largest area of the island. The vegetation of the rocky flat, which includes a great proportion of all the plant species of Iceland, may be divided according to soil conditions. On the higher plateaus, we find that the species and individuals become fewer in number and more scattered in growth (true fell-field), and these plants are usually stunted. On these elevated fell-fields mosses play an important part, especially *Grimmia hypnoides,* which gradually forms soil in which higher plants can grow. Fruticose lichens grow with the mosses, and "in many places on the plateau patches of *Anthelia nivalis* occur. The rocky-flat formation appears to be an original, late glacial formation . . . the different species having become associated according to their conditions of life. . . . As subdivisions, or nearly related formations, the following may be mentioned: gravelly flats (*melar*); stone-covered ridges (*holt*); fallen blocks and débris upon mountain slopes (*urd,* pl. *urdir*); steep cliffs (*hamrar*); gravelly river plains and river terraces (*eyrar*)," etc.

Gravelly flats (*melar*) also occupy large areas in the lowlands, the gravel being mixed with clay so that it cracks into polygonal cakes and forms a *rudemark.* These *rudemarker* greatly influence plant distribution, as the plants are generally confined to the gravel bands between the cakes, where they find shelter and protection. These gravel flats may be so poor in plant life that they appear quite bare and naked.

Fell-fields in South America and the European Alps

The *páramos* on the high mountains in South America from Ecuador to Venezuela are fell-fields with a typical open vegetation, the individuals scattered in clumps or of a cushion form, while the vegetation and its physiognomy on high African mountains are of similar character. On the *punas* in Chile we find that the arctic vegetation is composed largely of lichens and mosses scattered here and there over the surface. These are mountain steppes, the *punas* being poorer in species than the *páramos.*

The fell-fields are found in the Alps of Europe where both limestone and primitive rocks occur. The rubble, or talus, sets off the alpine plants which cling to the surface. In antarctic regions in South Georgia the plants form scattered cespitose tufts, as in *Poa caespitosa.* Dwarf shrubs occur and cushion plants, such as *Azorella caespitosa,* which is of a dirty-green color

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[5] Th. Thoroddsen: An Account of the Physical Geography of Iceland, With Special Reference to the Plant Life (The Botany of Iceland, Rosenvinge and Warming, edits., Part I: 2), Copenhagen and London, 1914, pp. 325-326.

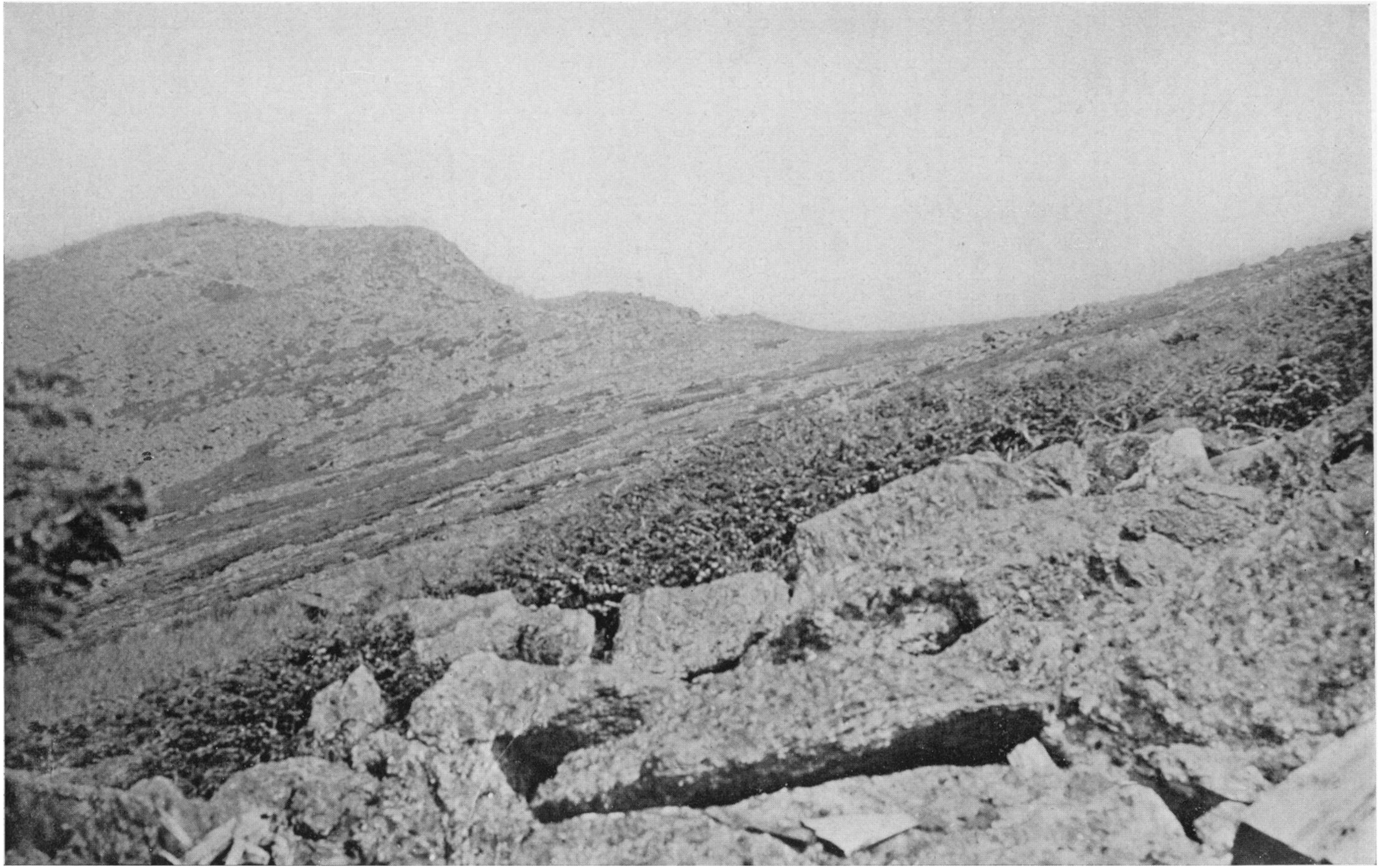

FIG. 3—Absolute tree line with low puckerbush and fell-field, western slope of Mt. Washington massif, August 23, 1918.

and more than a meter in height and is composed of little branches with scale leaves.[6]

THE FELL-FIELDS OF THE HIGHER MOUNTAINS OF THE EASTERN UNITED STATES

The preceding account will serve as an introduction to a study of the fell-fields of eastern North America which the writer has made in botanic exploration of the higher mountains of the eastern United States (see map, Fig. 1). It will enable the reader to appreciate the general principles upon which an investigation of the fell-fields on the summits of Mt. Katahdin in Maine (5,273 feet), Mt. Washington in the White Mountains of New Hampshire (6,290 feet), Mt. Marcy (or Mt. Tahawus, to use its Indian name) in the Adirondacks of New York (5,344 feet), and Mt. Mansfield in the Green Mountains of Vermont (4,364 feet) must be based. The areas on Mt. Marcy and Mt. Mansfield which represent fell-field are circumscribed.

THE FELL-FIELD ON MT. MARCY IN THE ADIRONDACKS

On Mt. Marcy, according to the observations of the writer made on August 26, 1914, the fell-field occupies the immediate summit and roughly covers several acres of rocky ground. Here is a relatively flat surface covered with large angular blocks of crystalline rocks which have resisted the action of the elements for ages. The open summit, just below which is a rock ledge behind which the writer's party took shelter from the icy blast, may be compared to an ellipse whose axis lies in a northeast and southwest direction but whose circumference is irregular. The trail leading down directly to Keene Valley, some distance below the summit proper, passes over smooth-surfaced ledges where the crystalline core of the mountain outcrops or has been denuded of its surface covering of soil and loose boulders. Here the smooth outcropping rock has been split by deep narrow fissures. Nearer the top similar smaller outcrops occur, so that the areas actually occupied by plants are few in number and small in size. Where the smoother surfaces do not occur the loose boulders cover the summit fell-field area. These boulders are variegated by the different colors of the lichens growing on their hard and almost naked surfaces. The rocks beneath the lichens are more soft and scaly than elsewhere. Between and beneath the tufts of rock-growing mosses the interspaces are filled with dust and sand, apparently composed of particles of disintegrated rock. Between the boulders and in the rock pockets we find particles of disintegrated rock, soil, and sand mingled with the stems and leaves of the mosses and other alpine plants, so that there is provided sufficient soil to permit the growth of the few low shrubs, prostrate balsams, and other characteristic species which grow on the summit. The boulders serve to protect the growing plants from the dry winds and icy blasts which blow across the mountain dome. The soil in most places is but a few inches deep, but as the rock crannies are filled with it and with loose rock fragments, the roots of the alpine plants can descend to considerable depths without opposition to their growth.

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[6] Additional data bearing on the botany of fell-fields will be found in the following: C. H. Ostenfeld: The Land Vegetation of the Faeroes (Botany of the Faeroes, 1908), pp. 990-996 (Fjaeldmark); R. Speight, L. Cockayne, and R. M. Laing: The Mount Arrowsmith District: A Study in Physiography and Plant Ecology, *Trans. and Proc. New Zealand Inst.*, Vol. 43, 1911, pp. 315-378 (see especially pp. 359-360); J. W. Bews: An Account of the Chief Types of Vegetation in South Africa, With Notes on the Plant Succession, *Journ. of Ecology*, Vol. 4, 1916, pp. 129-159 (see especially p. 135).

Its Characteristic Plants

On this circumscribed alpine fell-field of Mt. Marcy grow several interesting lichens. The soil-inhabiting ones are *Thamnolia vermicularis* (Fig. 4) with its white, frequently curled, quill-like thalli. The rounded cushions of the reindeer lichen, *Cladonia rangiferina,* are found; as is also Iceland moss, *Cetraria islandica.* The alpine club moss, *Lycopodium Selago,* is a fell-field plant; as also are such flowering plants as *Arenaria groenlandica, Potentilla tridentata, Cornus canadensis, Vaccinium pennsylvanicum* var. *angustifolium, Nabalus Boottii,* and *Ledum groenlandicum.* In the lee of rock ledges *Diapensia lapponica* was found growing in its characteristic cushion form. *Salix uva-ursi* is a dwarf prostrate willow. The alpine rattlebox, *Rhinanthus crista-galli,* was found in flower at the summit, along with other plants which live protected in the soil pockets on rock ledges or in the crannies and crevices of the rough angular boulders or slabs of crystalline rock which lie in confusion on the dome-shaped top. Photographs of Mt. Whiteface (4,872 feet), 16 miles north of Mt. Marcy, show

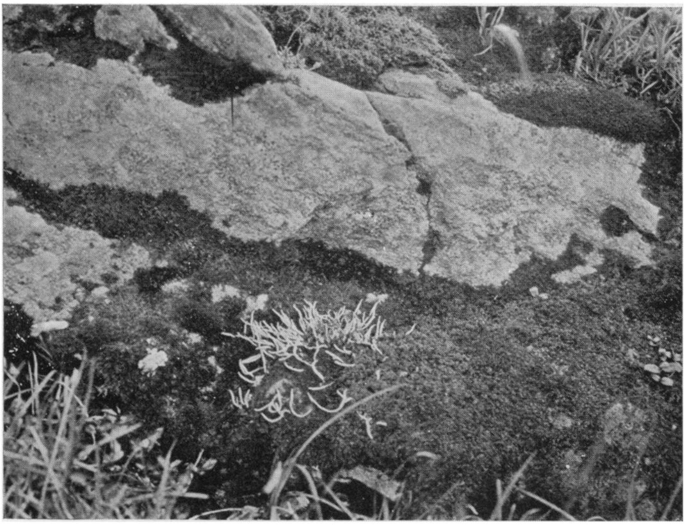

FIG. 4—The worm lichen (*contrayerba blanca*), *Thamnolia vermicularis*, growing out of a carpet of mosses found on rock ledges, head wall of Great Gulf, Mt. Washington, August 23, 1918.

similar conditions of fell-field, while Giant Mountain (4,622 feet) is not bare at the summit except where shelving rocks occur.[7]

THE FELL-FIELD ON MT. MANSFIELD IN THE GREEN MOUNTAINS

Fell-field may be said barely to exist on the summit of Mt. Mansfield except for the *arête,* or sharp ridge connecting the top (Chin) with the lower forest-covered parts (Nose) of the Mansfield massif.

THE FELL-FIELD ON MT. KATAHDIN

The top of Mt. Katahdin is an extensive plateau covered with tabular blocks or slabs of red granite, which increase in size upwards toward the West Peak, the highest point. The red granite on weathering splits into blocks more or less regular in form which strongly resemble courses of crumbling masonry. So friable is this rock that it crumbles readily, giving rise to a residual granitic soil which fills the rock crevices, rock pockets, and rock crannies as the original soil of the mountain. The slopes south from the two chief peaks are covered with loose, angular fragments as far down as the (so-called) tree line. The wind-swept balsam trees grow in the clefts between the confused, loosely piled blocks. Frost action has split these rocks into every conceivable form. The rocks of this fell-field formation are covered with the crustaceous lichen *Lecidea geographica,* whose thallus, alternately black and yellow, resembling a colored map, gives them a yellowish-green tone. Other crustaceous lichens begin as small patches and expand into mats and carpets which cover the boulders. *Tripe-de-roche, Umbilicaria* sp., as a rock lichen, accompanies the preceding form, as also several lithophytic mosses, such as *Andreaea petrophila, Rhachomitrium sudeticum,* and *R. aciculare.* The detritus produced by the wash, decay, and disintegration of the rocks, along with the organic remains of lichens and mosses, prepares a soil suitable for the reindeer lichen, *Cladonia rangiferina,* and Iceland moss, *Cetraria islandica.*

Accompanying the growth of these lichens, more material is accumulated to form a soil sufficient for the plants which characterize the alpine tundra. Here are such grasses, according to Harvey, as *Hierochloë alpina, Agrostis rubra, Deschampsia flexuosa;* such sedges as *Carex vulgaris hyperborea* and rushes as *Juncus trifidus,* accompanied by mosses such as *Mielichhoferia nitida elongata, Polytrichum commune, P. juniperinum* and *P. ohioensis.* In the ecologic succession of plants on this alpine fell-field, *Lycopodium annotinum* var. *pungens, L. Selago, Arenaria groenlandica,* and *Potentilla tridentata* appear or live side by side with the lichens and mosses above mentioned.[8] This is explained by different summit areas being in a more advanced or more retrograde stage of physiographic and edaphic development. Later the low heaths appear, some growing normally only when sheltered by some projecting slab of granite. The pioneer heaths are *Vaccinium pennsylvanicum* var. *angustifolium*, V. *uliginosum*, *V. Vitis-Idaea*, and the cushioned *Diapensia lapponica*. Of less frequency are *Ledum latifolium*, *Arctostaphylos alpina*, *Rhododendron lapponicum*, *Cassiope hypnoides*, *Loiseleuria procumbens*, and *Phyllodoce caerulea* (*Bryanthus taxifolius*).

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[7] J. W. Harshberger: The Plant Formations of the Adirondack Mountains, *Torreya,* Vol. 5, 1905, pp. 187-194; *idem:* Phytogeographic Survey of North America (Die Vegetation der Erde, Vol. 13), Leipzig and New York, 1911, pp. 405-408.

[8] J. W. Harshberger: A Botanical Ascent of Mt. Katahdin, Maine, *The Plant World,* Vol. 5, 1902, pp. 12-28. The ascent was made by the writer on August 1, 1900.

The conditions on this table-land are very severe, and some of the plants mentioned only succeed by growing in the shelter of the granite blocks or by sending their roots down to considerable depths in the rock crannies. *Arenaria groenlandica*, with its multitude of rootlets and its branching habit, can do this, as well as *Rhododendron lapponicum;* while *Arctostaphylos alpina*, *Vaccinium uliginosum*, etc., grow in spreading mats.[9] Even on the summit fell-field the alpine mats are encroached upon by dwarf prostrate trees such as *Betula glandulosa* and *B. papyrifera minor*, which, gradually increasing in number as the slopes are reached, merge with the dwarf timber at the tree line, viz. the puckerbush, or *krummholz*. The scattered condition of the alpine fell-field plants is emphasized in the tufted growth of several grasses, sedges, and rushes like *Juncus trifidus* and *Scirpus caespitosus*. A number of other species are characteristic of this alpine garden, where, as the moisture content of the soil increases because of the presence of a spring or where the snow remains well into the summer months, the fell-field conditions pass over into the alpine meadow societies.[10]

Two kinds of granite are found on Mt. Katahdin, the red kind, previously mentioned, and a gray kind, composing the lower two-thirds of the basin walls. These two granites are probably ultimately of the same character. The brownish-red granite, which concerns us in this paper, has been studied by Dr. M. E. Wadsworth.[11] He notes that the feldspars are colored pink and greenish white and that the calcite and a greenish talcose mineral occur as alteration products. In their section the feldspar is seen to be altered greatly and the biotite is partly decomposed. The structure of this red granite, which covers the upper 700 feet of the mountain, has determined the character of the summit and the form of the upper slopes and therefore, directly, the distribution of the trees and the other plant life of the summit.

Fell-fields of the Mt. Washington Massif

THE REGION INVESTIGATED

The fell-field of the alpine portion of the Mt. Washington massif is the particular theme of this paper. Three days were spent by the writer on the top of Mt. Washington—July 18-20, 1903—in the investigation of its alpine flora. The survey included the summit, the slopes, the Alpine Garden, and the head walls of the Great Gulf and Tuckerman Ravine (for locations, see map, Fig. 2). It enabled the writer to become familiar with the general topography, geology, and vegetation of the mountain, and the fact that the Alpine Garden represented a fell-field was impressed upon him. A number of articles setting forth his impressions appeared in *Among the Clouds,* a paper printed on the top of the mountain.[12] A second visit to Mt. Washington with the specific object of photographing and studying the fell-fields was made on foot from Bretton Woods, and two days—August 23-24, 1918—were passed in a study of the vegetation of the head walls of the Great Gulf and Tuckerman Ravine, the Alpine Garden, and the fell-fields elsewhere on the summit and about the Lakes of the Clouds.

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[9] No attempt is made in this account of fell-fields to enumerate all of the plants found on the mountains described. Only a few representative species are mentioned.

[10] L. H. Harvey: A Study of the Physiographic Ecology of Mt. Ktaadn, Maine, *University of Maine Studies No. 5*, Dec., 1903.

[11] C. E. Hamlin: Observations upon the Physical Geography and Geology of Mt. Ktaadn and the Adjacent District, *Bull. Museum Comp. Zoöl.*, Vol. 7, Cambridge, Mass., 1881, pp. 189-223; reference on p. 209.

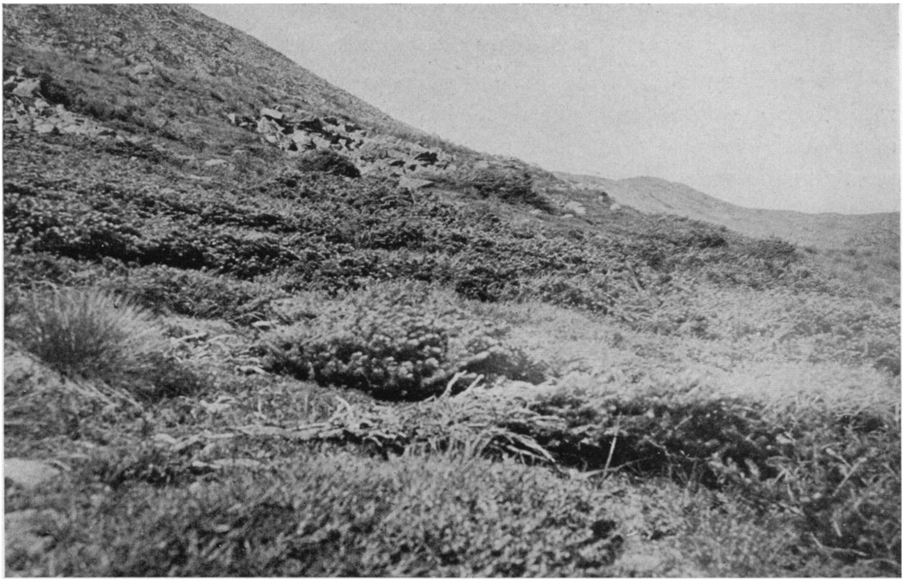

FIG. 5—Prostrate balsam trees (*Abies balsamea*) on the upper slopes of the Alpine Garden, Mt. Washington, August 23, 1918. To the left is a tussock growth of *Scirpus caespitosus.*

NATURE OF THE DOME

The summit and slopes of the dome of the Mt. Washington massif are a jumble of large slabs and boulders of granite. On the shoulders near the summit, as at the head of the Great Gulf, the coarse alpine sedges and grasses form an almost continuous sward, broken only by flat granite blocks which hardly rise above the grassy surface. Here alpine grassmeadow conditions are simulated; but the flora of these areas—an unusual condition on alpine summits—is a scanty one. Elsewhere on the alpine flanks of the dome the rocks are piled up in the greatest confusion, many of them covered with lichens and mosses. They are hoary with age and exposure to the severe meteorologic conditions. Pockets of earth are found of greater or lesser size, and great rifts in the rocks are almost cavernous in their extent. The drainage of such soils must be nearly perfect, as is evidenced by the successful growth of many alpine species which do not flourish in an ill-drained soil.

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[12] ".Our Mountain Flora," July 18, 1903; "The Great Gulf," July 23, 1903; "The Individuality of Mountains," Sept. 8, 1904.

Water Supply of Alpine Plants

The rocky surface, however, serves as a protective check against too rapid loss of water from the soil, so that by growing down deeply the roots of most alpine plants are able to get the necessary water supply, as the plants have various structural or anatomic details by which the loss of the absorbed water is more or less completely regulated. It has been the experience of gardeners that numbers of alpine plants perish if planted in the ordinary soil of our gardens. But many of these rock plants, if so placed that their roots are in a dry spot, remain in perfect health. Many plants from mountains a little farther south and from alpine regions find on walls congenial conditions for healthy growth. A wall properly constructed for the growth of alpines ensures comparative dryness in winter and assures against drought in summer. This apparent paradox is easily explained, for the heavy rains and snow water of winter will pass through a mass of broken stone more readily than through a similar body of soil, and in summer the stones of the wall prevent loss of water by evaporation. Such a wall, therefore, drains away superfluous water but conserves the precious minimum supplies upon which alpine plants depend. Probably everyone has noticed, on removing a large stone, that the soil beneath it is moist while the surrounding soil not similarly covered is dry. So beneficial to the roots is contact with the cool stones that plants which would perish from drought in the lighter soils remain fresh and green in a rock wall under the hottest exposure, since there is moisture deep in the crevices. In the fall of the year the rock plants become thoroughly "ripened" and their tissues hardened by exposure to the heat of the sun and stones in contact with their roots, stems, and leaves.

Extremes of Temperature on Mountain Summits

Similarly the alpine fell-field is exposed to intense illumination, and the soil heats up rapidly in the daytime; but after sundown it parts with the heat with equal rapidity, so that on a clear evening it becomes intensely cold. A similar difference is noticeable between the sunny and the shady places on high mountains, as the writer experienced on the Gorner Grat (10,290 feet) some years ago while botanizing in the Swiss Alps. Here at noonday the soil and stones on the north side of the shelter hut were frozen hard, while on the south side the soil had thawed to the depth of one or two inches, so that the larger stones could easily be removed.

Aspect and Soil

Aspect, or exposure, which may be defined as the point of the compass which any sloping land faces, is of great importance in the distribution of alpine plants. This is true especially on Mt. Washington, for the head wall of the Great Gulf with its northern aspect supports a greater variety of alpine plants than the top of Mt. Washington itself. A minor feature of this exposure is seen on the flatter slopes of the fell-field proper, where the level is broken by the rocks, which provide different aspects and drier or moister positions. These rocks vary from true rock ledges through blocks, boulders, slabs, loose angular pieces, cobblestones, pebbles, etc., to coarse gravel and sand, which, sorted by glacial action, winds, snow, and rains, provide the edaphic environment of the hardy alpine plants. These comprise earth-inhabiting or rock-inhabiting lichens and mosses (lithophytes) and the soil-growing flowering plants which are able to grow because of their various root adaptations and because such plants have regulatory aërial structures to control transpiration and to adjust themselves to other influences of an alpine climate. Schröter[13] divides the plants of the fell-fields, as to their habits of growth with reference to the soil, into (1) earth-inhabiting plants (lichens, mosses, and seed plants); (2) shingle-inhabiting (seed) plants; and (3) rock-inhabiting plants (lithophytes), which include

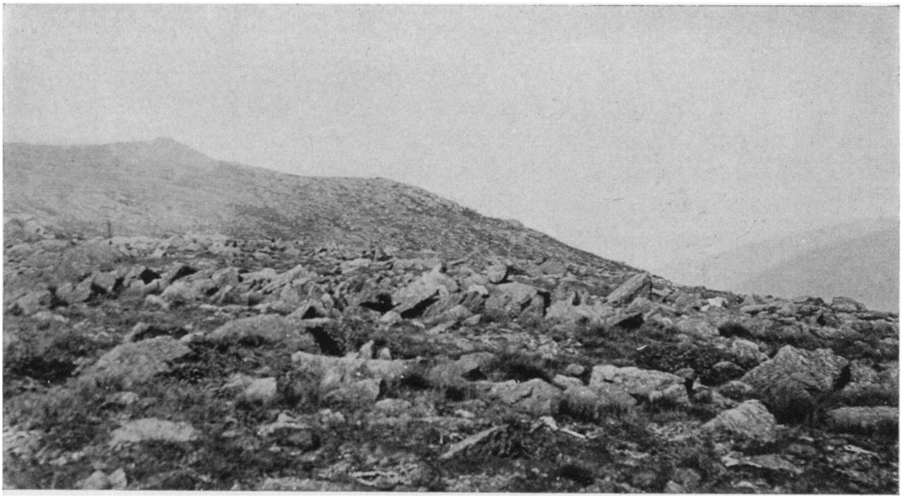

Fig. 6—Fell-field of the Alpine Garden, Mt. Washington, August 23, 1918. Note round cushions of *Diapensia lapponica* in the foreground.

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[13] C. Schröter: Das Pflanzenleben der Alpen, 1908, p. 514.

surface-growing mosses and seed plants, crevice plants, rock-penetrating plants (lichens and mosses), and rock-attached plants (algae). The lichens and mosses have rhizoids, while the seed plants have true roots. The earth-inhabiting plants (chomophytes) may grow in clay, loam, sand, or fine gravel soils, etc. Oettli calls[14] the rock-surface plants exochomophytes to distinguish them from the preceding alpine plants and from those which accommodate their growth to the rocky clefts and fissures of the fell-field surface (chasmophytes).

VEGETATION OF THE MOUNTAIN SHOULDER NEAR JACOB'S LADDER

Having considered the general conditions of soil and aspect of the alpine fell-fields of Mt. Washington, it is next important to treat of the specific details which were investigated during the summer of 1918. Jacob's Ladder, on the mountain railroad, has long been celebrated for its trestle spanning one of the steepest grades of the ascent. Off from the trestle there is a relatively flat place formed by a projecting shoulder of the mountain. Large slabs of granite are piled up in a cairnlike ridge, and behind this pile of rocks low, spreading, wind-swept balsam trees, *Abies balsamea,* are found, the tops of the trees just reaching to the crest of the lichen-covered rocks (Fig. 3). Here the Labrador tea, *Ledum groenlandicum,* forms extensive masses of low shrubbery, as likewise do the low and spreading bushes of the bog bilberry, *Vaccinium uliginosum,* and the still more dwarfish low, sweet blueberry, *Vaccinium pennsylvanicum* var. *angustifolium,* together with the low creeping stems of the mountain cranberry, *Vaccinium Vitis-Idaea,* with its erect branches and dark red berries in late summer shining between the dark, evergreen leaves. The roots of these three plants are specialized in the possession of endotrophic mycorrhiza, which, some botanists have suggested, absorb the nitrogen of the air and assimilate it. The crowberry, *Empetrum nigrum,* is a many-branched undershrub seldom over two feet tall and with many earth-creeping stems covered with numerous short, awl-shaped leaves of the ericoid type. It forms dense, dark green, cushion-like growths. Tufts of *Lycopodium annotinum* var. *pungens* are scattered between the rocks on the level places, together with the rounded pincushion-like plants of *Diapensia lapponica.* The three-toothed cinquefoil, *Potentilla tridentata,* the bunchberry, *Cornus canadensis,* and the creeping snowberry, *Chiogenes hispidula,* sending out long, running shoots over the bare ground or over the moss-covered rocks, contribute their growth to the Japanese garden effect of the vegetation of this mountain shoulder. One other plant growing out of the moss cushions is a noteworthy cosmopolitan lichen, *Thamnolia vermicularis* (the worm lichen), found also by the writer in moss carpets of the head wall of the Great Gulf (Fig. 4). The chalk-white, cylindrical, twisted podetia of this lichen suggest the name applied to it by the mountaineers of the Peruvian Andes, *contrayerba blanca.*

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[14] M. Oettli: Beiträge zur Ökologie der Felsflora (Zurich Polytechnic Institute thesis), Zurich, 1905.

Castilleja pallida var. *septentrionalis,* the white painted cup, is a perennial growing out of the rock crevices. The true alpine club moss, *Lycopodium Selago,* also occurs here.

VEGETATION OF THE ALPINE GARDEN

Climbing down the treacherous rocks below the hotel on the top of the mountain to the plateau known as the Alpine Garden, about a thousand feet below, abundant masses of the Labrador tea, *Ledum groenlandicum,* were found filling up the flatter depressions between the blocks of granite, which appear as if they had slipped down the mountain side. *Phyllodoce caerulea (Bryanthus taxifolius)* is a low, alpine, heathlike undershrub, which is more abundant on these mountain slopes between the granite boulders than on the declivities of the Great Gulf, where it was collected by the writer in 1903. Here also the interspaces of the rocks were occupied by the low shrubs of the bog bilberry, *Vaccinium uliginosum,* with its twisted stems prostrate between the rough boulders. Occasionally on the descent patches of meadow sweet, *Spiraea latifolia,* in full flower were passed, contributing their quota to the rock-garden effect. The upper slopes of the Alpine Garden are covered with dense tangled thickets of balsam trees, *Abies balsamea,* which form the puckerbush, dwarf timber, or *krumm-*

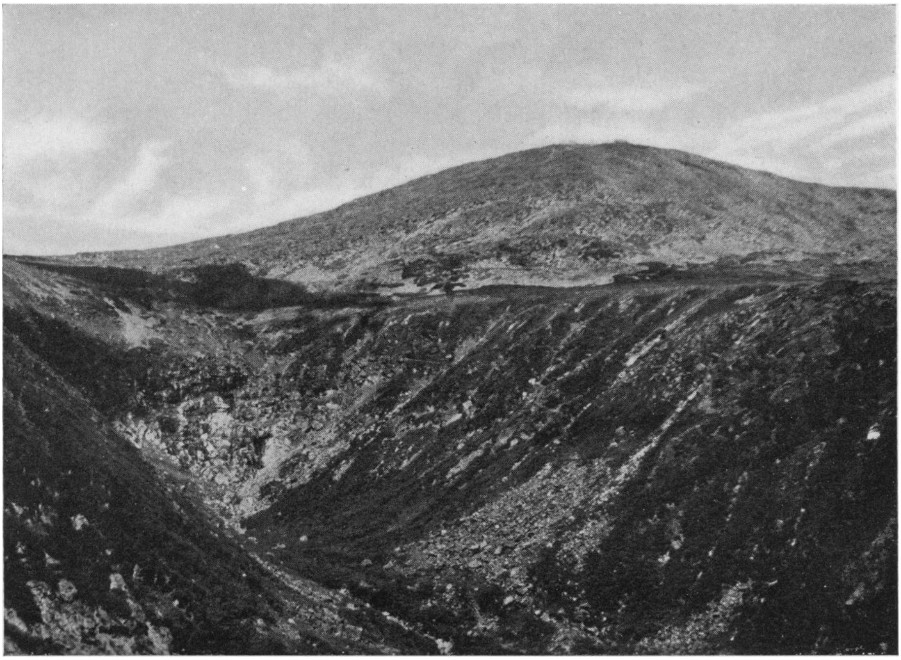

FIG. 7—The summit dome of Mt. Washington seen across Tuckerman Ravine. The intervening platform is the Alpine Garden, terminating in Lion Head in the right foreground. Notice the flat shelf on the left connecting the Garden with the shoulder between Mt. Washington and Mt. Monroe.

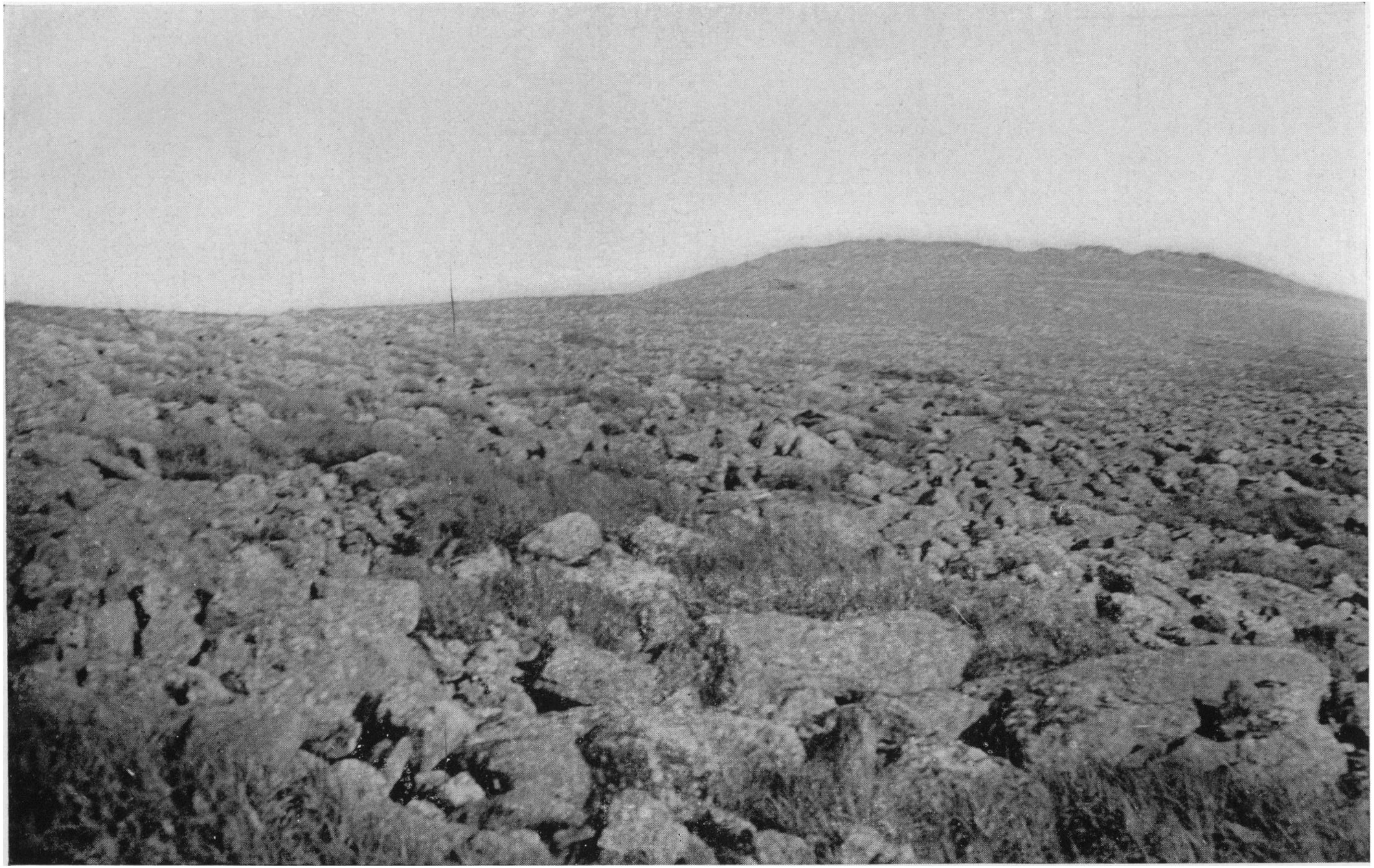

FIG. 8—Typical fell-field in the saddle between Mt. Washington and Mt. Monroe, looking toward Boott Spur (about 5,500 feet), August 23, 1918. Note the coarse grasses and other alpine plants between the slabs of granite.

holz (Fig. 5) through which the writer forced his way or over the tops of whose interlaced branches he walked without slumping through. Balsam trees at the elevation of the Alpine Garden (5,500 feet) rarely produce seed. Reproduction depends not only on seeds blown up from below but mainly on the layering of the trees. The roots always develop from the prostrate branches, and the branches so layered often develop as independent trees by the decay of the connecting branch. Cones are born sparingly at 4,900 feet, and even here reproduction by layering exists. The scrub forms of balsams extend down to 4,500 feet, while the trees of merchantable size begin to appear at 4,000 feet. On the alpine stretches of the Presidential Range the dwarf trees are very shallow-rooted, needing only a mossy bed for the seeds to germinate. The balsam can grow almost on bare rocks, if it starts its growth in a mossy cushion covering the rock. There are some bare areas here where the balsams do not grow (Fig. 5), and these are characterized by cushions of the alpine willow, *Salix herbacea,* and tussocks of the dense, stiff, erect wirelike stems of the sedge *Scirpus caespitosus.*

Along Six Husbands Trail, which crosses the flatter portions of the Alpine Garden plateau (Figs. 6 and 7), we find the fell-field vegetation to consist of numerous low cushions of *Diapensia lapponica,* the basketlike growths of *Phyllodoce caerulea,* and the isolated clumps of the white painted cup, *Castilleja pallida* var. *septentrionalis,* one of the few plants in flower late in August, 1918. Here also are tufts of bitter cress, *Cardamine bellidifolia* var. *laxa,* in fruit. The reindeer lichen, *Cladonia rangiferina,* reminded one of its cosmopolitan distribution in the high North, where it forms one of the important foods of the Lapland reindeer. The roundheaded clumps of *Rhododendron lapponicum* relieve the rocky surface. Near the end of Six Husbands Trail the source of the stream which descends through Tuckerman Ravine is found in wet places, fed by springs which emerge from the loosely piled rocks of the massif above. Here are numerous plants of the green hellebore, *Veratrum viride,* growing out of a sphagnum carpet, while the cold spring water is characterized by masses of some bright-green filamentous alga.

Conditions of Saddle between Mt. Washington and Mt. Monroe

The depression of the Presidential Range between Mt. Washington and Mt. Monroe flattens out into a plateau, or fell-field (Fig. 8), which is the source of two important streams rising in springs which gush from the loosely piled blocks of granite. The source of the Tuckerman Ravine affluent of the Cutler River (Fig. 7), feeding Hermit Lake in the bottom of the ravine, has been noticed as being on the east side of the range. On the western side the volume of the springs is sufficient to supply two mountain tarns, known as the Lakes of the Clouds, the outlet of which is the source of the Ammonoosuc River. Near this outlet stands the new Appalachian

Mountain Club Hut, formally opened on August 7, 1915. This plateau holds the Lakes of the Clouds, and the mirrorlike surfaces of their waters reflect the rocky shores and the mountains in the background. The plateau is really a continuation of the Alpine Garden, which terminates in the Lion Head above Tuckerman Ravine (Fig. 7). Northeastward the Alpine Garden is bounded by Huntington Ravine. The elevation of this plateau is between 5,000 and 5,500 feet, for its surface is undulating in its extent from Huntington Ravine around the head of Tuckerman Ravine to Boott Spur and the eastern slopes of Mt. Monroe. Here, as along the upper slopes of the Alpine Garden, the dwarf timber, or puckerbush, pushes up the mountain in favorable protected places so that, as the photographs show (Figs. 3 and 5), the absolute timber line, represented by the extension upward of the dwarf prostrate balsam, *Abies balsamea,* is not many hundred feet below the top of Mt. Washington. Descending from the hotel on the summit of the mountain, just before the more level Alpine Garden was reached, the writer had to force his way through the dwarf timber. In some cases he walked some distance on the tops of the prostrate trees, in accomplishing which feat he recalled Thoreau's account of a similar trip up Mt. Katahdin.[15]

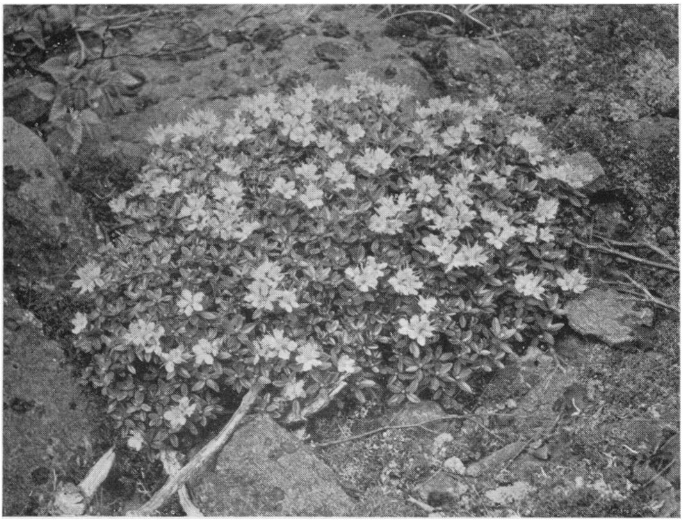

FIG. 9—Rounded shrub of Lapland rosebay (*Rhododendron lapponicum*) in flower on fell-field, Mt. Madison, N. H. (at 5,000 feet), June 25, 1917. (Photo by Ralph E. Cleland.)

As one looked along the saddle towards Boott Spur and Mt. Monroe the spaces between the rocks were seen to be occupied by rushes, sedges, and grasses (Fig. 8). Several species of the genera *Carex, Juncus,* and *Scirpus* were noted, either in isolated cushions (tussocks) or covering an extended soil surface and giving rise to a dry alpine meadow.[16] On Mt. Washington *Scirpus caespitosus* is one of the most important of the tussock sedges. Few alpine plants grow amongst the tough, wiry, grasslike plants. Off from the grassy stretches were found masses of *Salix herbacea,* as well as the rounded cushions of *Arenaria groenlandica* and *Rhododendron lapponicum* (Fig. 9) in full flower on August 23, 1918. Here, as the western slopes of the saddle were approached, were found isolated clumps of balsam trees spread over the rocky fell-field.

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[15] H. D. Thoreau: The Maine Woods, Boston, 1864, p. 61.

Bryophytes form, as in Iceland, a prominent part of the vegetation of this rocky flat. The dry flat is often poor in plants and occasionally devoid of vegetation. The mosses occur in scattered cushions, especially around somewhat large stones, where they can hold fast and find some shelter. In somewhat damper and less exposed areas moss heaths are developed, as on the lava fields of Iceland. On somewhat damper ground, especially where large blocks lie scattered and afford shelter, the mosses become richer and form a continuous carpet. As on the slopes of the head wall of the Great Gulf, there are places on this saddle where the creeping stems of *Salix herbacea* are interwoven in a dense moss carpet, so that only the tips of the moss shoots project above the carpet. Helgi Jónsson has called attention to somewhat similar conditions on the rocky flats of Iceland.[17] On dry stony tracts there often occurs a continuous, though circumscribed, growth of mosses. Here the higher plants grow scattered without giving character to the vegetation. These areas, as in Iceland where they are more extensive, may be called moss heath patches. By the decay of the mosses a humus layer is gradually formed.

Fell-field about the Lakes of the Clouds

The fell-field about the Lakes of the Clouds is characterized by a richer alpine flora than elsewhere; and, because of the larger amounts of permanent soil water, not only does the number of individuals of any one species increase, but also the number of species is augmented considerably. The shores of the two alpine tarns are rocky, with scattered blocks and slabs of granite, and at several places the rocks are shelving and precipitous (Figs. 10 and 11). The clear cold water of the lakelets, derived from springs beneath the rocks, does not support the usual aquatic plants. Similarly, the high alpine lakes of the Swiss Alps are devoid of flowering plants. In his enumeration of the vegetation of the lakes of the region of the Bernina Pass, Rübel[18] does not mention any of the higher plants but only diatoms, blue and green algae, which can perform their functions in the icy waters of these alpine tarns. The shores of the Mt. Washington lakelets, where the presence of large boulders does not prevent, are bordered by cushioned mosses and low, overhanging, prostrate shrubs and trees.

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[16] J. W. Harshberger: Phytogeographic Survey of North America (Die Vegetation der Erde, Vol. 13), Leipzig and New York, 1911, p. 377.

[17] The Botany of Iceland (Rosenvinge and Warming, edits.), Part II, Copenhagen and London, p. 591.

[18] E. Rübel: Pflanzengeographische Monographie des Berninagebietes, *Botan. Jahrbuch*, Vol. 47, 1912, pp. 1-616.

The flat places along the east shore of the upper lake are covered with cushions of mosses, some of a light-green color (Fig. 10). Rooting through these mosses, which are associated with light gray patches of the reindeer lichen, *Cladonia rangiferina,* we find the bog bilberry, *Vaccinium uliginosum,* in low, spreading bushes, and the crowberry, *Empetrum nigrum,* mixing its growth with that of the low, narrow-leaved blueberry, *Vaccinium pennsylvanicum* var. *angustifolium,* while out of the sphagnum, which in some places forms the boggy shore line, grows the yellow mountain avens, *Geum* (*Sieversia*) *Peckii,* with its flowers bending over the water's edge (Fig. 11). Sprawling over the flatter boulders, beside which its roots extend into the rock crevices, we find the graceful dwarf birch, *Betula glandulosa,* which ranges north to the Arctic regions, and nearby the Labrador tea, *Ledum groenlandicum,* forming low dwarf clumps of spreading bushes. *Lycopodium annotinum* is found here, and the green hellebore, *Veratrum viride,* forms societies in damp, boggy places with its light-green foliage outlined against the dark-green mosses of the prostrate, wind-swept balsam trees and protected from the wind by some large projecting mass of rock (Fig. 11).

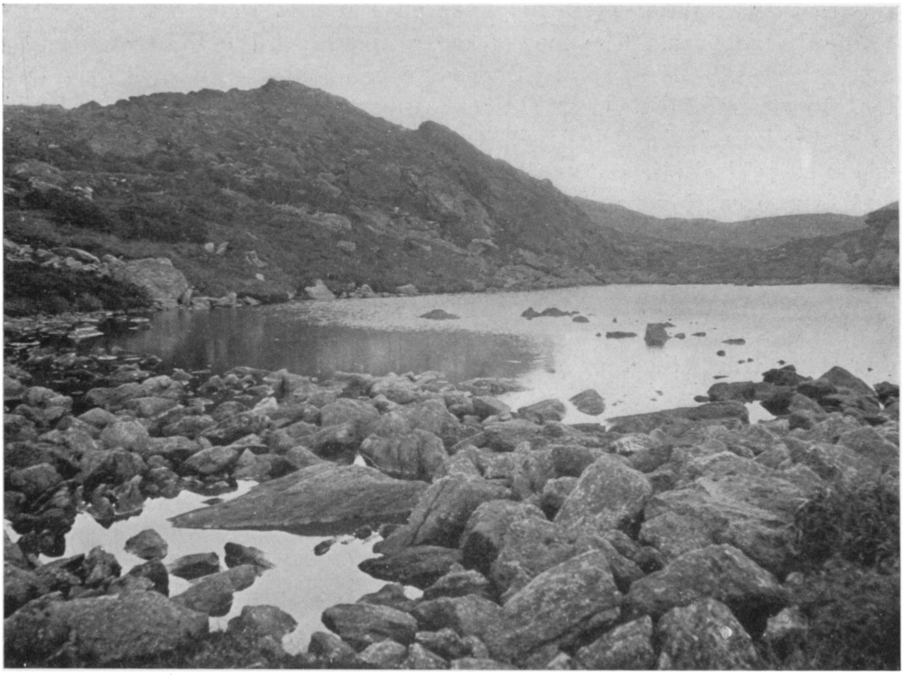

FIG. 10—Upper tarn, Lakes of the Clouds, Mt. Washington, August 24, 1918. The low shrubs on the slopes of the fell-field above the lake are seen in the background. The outlet is in the foreground.

Cushions of hair mosses, *Polytrichum,* vary the colors of the fell-field vegetation along the shores of the upper lake, as do meadow-sweet, *Spiraea latifolia,* bunchberry, *Cornus canadensis,* and mayflower, *Maianthemum canadense.* The outlet of this tarn (Fig. 10) is by a channel which leads to the edge of the head wall of the Ammonoosuc Ravine. In late summer this outlet is dry, but the rounded cushions of hair mosses, separated from each other by narrow or wide spaces, indicate the direction of the overflow channels in wet weather. The west shore of the upper lake is more precipitous, the strongly fissured ledges rising vertically from the water. Among the rock mosses grow twisted balsams, *Abies balsamea,* spreading outward over the flatter places. A few of these dwarf trees have twisted trunks as large as a man's leg. The less rocky slopes are covered with low bushes of the Labrador tea, *Ledum groenlandicum,* and bog bilberry, *Vaccinium uliginosum,* while on the flat, bare soil spaces hereabout are cushions of *Diapensia lapponica,* reindeer lichen, *Cladonia rangiferina,* spreading growths of mountain cranberry, *Vaccinium Vitis-Idaea,* with red fruit. Spreading masses of crowberry, *Empetrum nigrum,* also contribute their quota to the vegetable covering of the fell-field, where the boulders support various rock-growing lichens, such as *tripe-de-roche, Umbilicaria.* The rifts or depressions between two of the large boulders

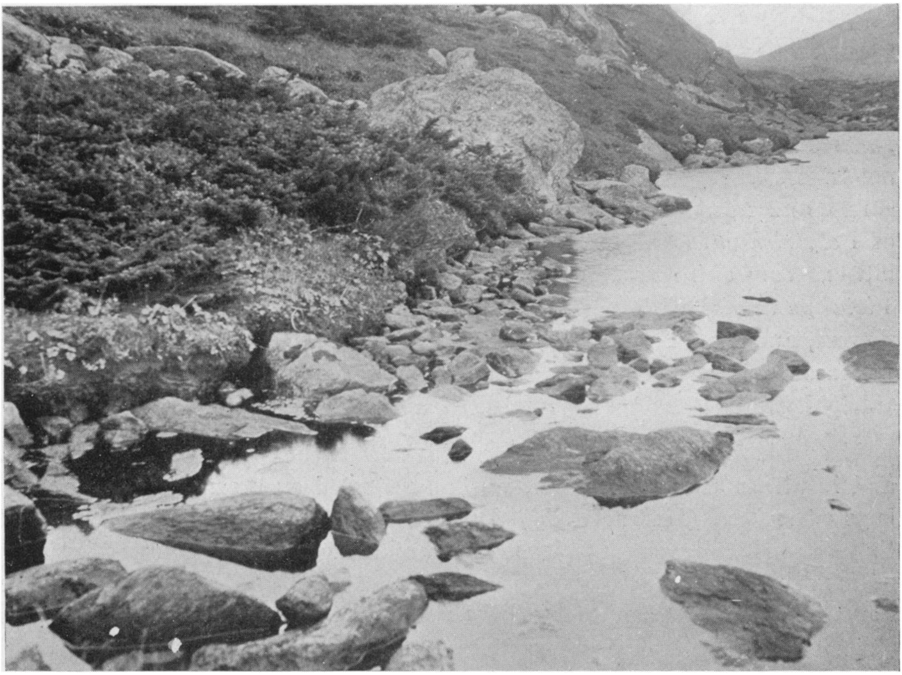

FIG. 11—Lower tarn with prostrate balsam trees fronted by moss cushions of the moss bog and the loose rocks of the lake shore, Lakes of the Clouds, Mt. Washington, August 24, 1918.

are characterized by the bunchberry, *Cornus canadensis, Clintonia borealis, Vaccinium pennsylvanicum, V. Vitis-Idaea,* and *Potentilla tridentata.* An especially deep rift protected the dwarf mountain birch, *Betula pumila,* which scarcely reached to the top of the boulders between which it grew.

The slopes of the fell-field around the lower lake are less steep. In late August a stream of crystal water issued forth among the rocks as its outlet. Over this outlet stream spread the branches of dwarf balsams, dwarf birches, *Betula glandulosa,* dwarf willows with dark-green, lustrous foliage, *Salix phylicifolia.* Bog bilberry, *Vaccinium uliginosum,* hangs over the stream of water as it gurgles among the rocks and among mossy cushions of *Polytrichum* and *Sphagnum,* out of which grows the yellow mountain avens, *Geum Peckii.* Here are also tufted growths of *Arenaria groenlandica* (Fig. 12) among the rocks, and the photograph shows how the rocks are arranged in forming the surface of the alpine fell-fields hereabout. *Salix argyrocarpa* also fringes the outlet stream as a low, spreading shrub, and nearby is *Salix uva-ursi.* The shore line consists of soft beds of *Polytrichum, Sphagnum,* and other alpine mosses. Out of them grow bluets, *Houstonia caerulea* var. *Faxonorum,* gold thread, *Coptis trifolia, Viola palustris,* with round cordate to reniform leaves and pale lilac flowers, and the yellow avens, *Geum Peckii.* Other flowering plants occur in season.

Alpine Moss Bogs

Near where the principal spring which feeds the lower tarn issues forth, and in places around its shore, we find repeated on a small scale the moss bogs of Iceland (Icelandic, *dý*) described by Helgi Jónsson.[19] In Iceland they are bright-green moss carpets around and below the place of issuance of a spring, and they form one of the most frequent and characteristic plant communities of arctic and subarctic regions. Grönlund (1877) was perhaps the first ecologist to call attention[20] to the mats of green mosses along small streams on mountain sides. Moss bogs, which have their counterpart on a small scale around the Lakes of the Clouds on Mt. Washington, develop in Iceland on muddy soil in all places where water emerges as a spring. They occur on mountain slopes, at the bottom of valleys, and also at higher levels on rocky flats. There the mosses grow scattered in bright-green patches differing greatly in size and conspicuous even at a distance by their color, which is distinct from that of the deeper greens of the surrounding plants. These mosses on Mt. Washington, as in Iceland, are subjected to the influence of cold, well-aërated water, which determines the character of the plant associations. During the summer the low temperature of the water, also influenced by evaporation from the moss surface, acts as a check to the growth of the higher plants and is, therefore, indirectly favorable to the moss vegetation. The distribution of mosses and the higher plants is also due to the character of the substratum —whether gravelly or muddy.

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[19] Work cited in footnote 17.

[20] Chr. Grönlund: Islandske Naturforhold, *Tidsskr. for populaere Fremst. af Naturvidensk.*, 5 R, Vol. 4, 1877, pp. 321-356.

Conclusion

In conclusion the writer believes that comparative ecologic studies, such as this, are important for the classification of our knowledge concerning the fundamental units of vegetation the world over. We have reached a stage in our investigations where it is profitable to compare American plant formations with those of Europe and other parts of the world. The writer has attempted to make this correlation with reference to the fell-field formation, and in another place he has made a comparative study of American and European heaths and pine heaths.[21] Few papers have hitherto appeared in which such comparisons have been made. This field of research is one that promises substantial progress in our elucidation of the problems confronting us in a study of American units of vegetation. The three international phytogeographic excursions have done much to stimulate this kind of comparative investigation, and those which will follow will undoubtedly stimulate the same kind of inquiry.

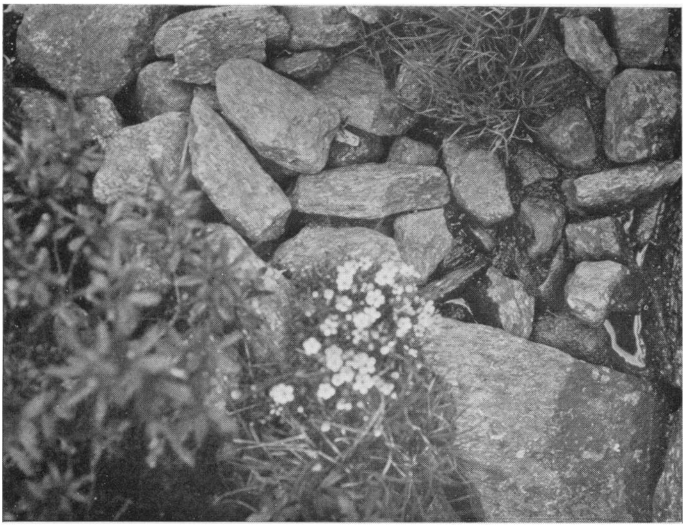

FIG. 12—*Arenaria groenlandica* as a cushion plant in flower growing out from the crevices of the loose rocks of the fell-field near the outlet of the lower Lake of the Clouds, August 24, 1918.

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[21] J. W. Harshberger: American Heaths and Pine Heaths, *Brooklyn Botanic Garden Memoirs*, Vol. 1, June 6, 1918, pp. 175-186.